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**(54) Composition for tread rubber of tires**

(57) A rubber composition suitable for use in tread of tires, have excellent rolling characteristics and abrasion resistance and an improved dimensional stability as not causing shrinkage when extruded into rubber sheets for treads, which comprises a rubber component; 20 to 60 parts by weight of silica, 3 to 12 parts by weight of a silane coupling agent, and 2 to 10 parts by weight of a short fiber, respectively, per 100 parts by weight of the rubber component.

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## Description

The present invention relates to a rubber composition suitable for use in treads of tires having improved characteristics such as rolling characteristics and abrasion resistance and having an excellent dimensional stability, and more particularly to a rubber composition for tire treads containing a short fiber filler.

For achieving fuel cost reduction increasingly required for recent cars, it is required to decrease the rolling resistance of tires. Various rubber compositions for tire treads are proposed in order to decrease the rolling resistance of tires.

It is known that the rolling resistance is decreased by incorporating carbon black in a decreased amount or a low grade of carbon black into a rubber composition for tire treads. However, this method has a problem that the abrasion resistance of treads is deteriorated.

In order to provide a rubber composition for tire treads which can decrease the rolling resistance without deteriorating the abrasion resistance, it is proposed to incorporate silica and a silane coupling agent as reinforcing materials other than carbon black. However, such a rubber composition containing silica and a silane coupling agent has a tendency that the shrinkage of extrudates of the composition becomes large. Thus, management of process steps is difficult.

In general, an extruded tread causes a slight shrinkage in the direction of extrusion. In particular, rubber compositions having a small content of a filler contemplated to provide low fuel cost tires have a larger tendency of shrinkage. Also, the shrinkage is particularly large in the vicinity of cut position of an extruded rubber sheet, so the rubber sheet becomes thicker at the cut portion. If tires are produced by using a tread rubber sheet having an increased thickness in the vicinity of the cut portion due to the shrinkage, the thickness in the vicinity of the tread joint becomes large, thus resting in lowering of the roundness of tires which may cause vibration of cars in running.

It is an object of the present invention to provide a rubber composition suitable for use in tire treads having excellent characteristics such as rolling characteristics, abrasion resistance and dimensional stability.

A further object of the present invention is to provide a rubber composition suitable for use in tire treads containing silica as a reinforcing material, which is improved in dimensional stability.

These and other objects of the present invention will become apparent from the description hereinafter.

It has been found that the shrinkage of a rubber sheet extruded from a rubber composition containing silica and a silane coupling agent can be prevented to improve the processability of the composition and to provide tires having an excellent dimensional stability by incorporating a small amount of a short fiber into the composition.

In accordance with the present invention, there is provided a rubber composition suitable for tire treads comprising a rubber component, 20 to 60 parts of silica, 3 to 12 parts of a silane coupling agent, and 2 to 10 parts of a short fiber, said parts all being parts by weight per 100 parts by weight of said rubber component.

The rubber composition of the present invention has excellent rolling characteristics as required to provide low fuel cost tires and an excellent abrasion resistance, since it contains silica as a reinforcing material. Moreover, the rubber composition is remarkably improved in dimensional stability which is deteriorated by incorporation of silica. Thus, the rubber composition for tire treads of the present invention can provide low fuel cost tires having an excellent dimensional stability.

The kind of rubbers used as the rubber component of the composition of the present invention is not particularly limited. Diene rubbers such as natural rubber (NR), isoprene rubber (IR), butadiene rubber (BR) and styrene-butadiene rubber (SBR) and other known rubbers used in tire production can be suitably used alone or in admixture thereof.

The kind of silicon is not particularly limited. For instance, anhydrous silica (silicic anhydride) prepared by a dry process and hydrous silica prepared by a wet process, as known as white carbon are suitably used in the present invention.

Silica is used in a amount of 20 to 60 parts by weight, preferably 30 to 50 parts by weight, per 100 parts by weight of the rubber component. If the amount of silica is less than 20 parts by weight, the reinforcing effect is not sufficient and the obtained cured rubbers are inferior in abrasion resistance. If the amount is more than 60 parts by weight, the rolling characteristics are deteriorated.

Any of known silane coupling agents can be used in the present invention, e.g. silane coupling agents as represented by the formula  $\text{RSiX}_n$  wherein R is an organic functional group having vinyl group, glycidoxy group, methacryloyl group, amino group or mercapto group, X is a hydrolyzable group such as chlorine or an alkoxy group, and n is 2 or 3, such as bis(triethoxysilylpropyl)tetrasulfide,  $\gamma$ -mercaptopropyltrimethoxysilane, or  $\gamma$ -glycidoxypropyltrimethoxysilane.

The silane coupling agent is used in an amount of 3 to 12 parts by weight per 100 parts by weight of the rubber component. If the amount of the silane coupling agent is less than 3 parts by weight, since a reaction between silica and rubber does not sufficiently proceed, sufficient reinforcement is not obtained and the abrasion resistance is deteriorated, and the rolling characteristics are also deteriorated. Even if the silane coupling agent is used in an amount of more than 12 parts by weight, a further reinforcing effect is not substantially obtained, while the cost increases, thus impractical. Although the amount of the silane coupling agent can be suitably selected within the above-mentioned range, it is efficient to use the silane coupling agent in an amount of about 10 % of the amount of silica used.

The short fiber orients in the direction of extrusion when the tread rubber composition is extruded in a usual extrusion step to form a rubber sheet for tire tread, and serves to inhibit the shrinkage of the rubber sheet.

Short fibers having an average diameter D of 0.1 to 0.5  $\mu\text{m}$ , preferably 0.2 to 0.4  $\mu\text{m}$ , an average length L of 50 to 500  $\mu\text{m}$ , preferably 100 to 400  $\mu\text{m}$ , and an L/D ratio of 100 to 5,000, preferably 300 to 2,000, are used in the present invention. If short fibers having dimensions outside the above ranges are used, no sufficient shrinkage-inhibiting effect is obtained or breakdown characteristics of rubber are deteriorated.

The materials constituting the short fibers are not particularly limited so long as the short fibers are organic fibers having dimensions within the above ranges. For example, there can be used a synthetic fiber such as nylon fiber, aramid fiber or polyester fiber, a semisynthetic fiber such as rayon fiber, and a natural fiber such as cotton fiber. The short fibers may be used as they are, or may be previously surface-treated with a known coupling agent in order to improve the adhesive property to a rubber.

Such short fibers are commercially available.

The short fiber is used in an amount of 2 to 10 parts by weight, preferably 3 to 5 parts by weight, per 100 parts by weight of the rubber component. If the amount of the short fiber is less than 2 parts by weight, sufficient shrinkage-inhibiting effect is not obtained, and if the amount is more than 10 parts by weight, the abrasion resistance is remarkably deteriorated. The use of the short fiber in an amount of 3 to 5 parts by weight is preferred, since the shrinkage is inhibited without greatly affecting the physical properties of cured rubbers.

It is preferable to further incorporate carbon black in addition to silica or to substitute carbon black for a part of silica as a reinforcing material other than silica. A high reinforcing carbon black having an iodine adsorption number of 100 to 190 mg/g is preferably used as a carbon black to be incorporated into the rubber composition for tire treads according to the present invention. Carbon black having an iodine adsorption number of 140 to 180 mg/g is particularly preferred from the viewpoint of abrasion resistance. If the iodine adsorption number is less than 100 mg/g, since the reinforcing ability is not sufficient, lowering of the abrasion resistance is brought about when the amount is small. If the iodine adsorption number is more than 190 mg/g, heat generation of rubber increases, thus deteriorating the rolling characteristics. Examples of the carbon black satisfying such a requirement are, for instance, N220 (iodine adsorption number 121 mg/g), N234 (iodine adsorption number 120 mg/g), N110 (iodine adsorption number 145 mg/g) and the like. Carbon black N110 is particularly preferred for the reasons mentioned above.

It is preferable that the amount of carbon black is at most 30 parts by weight per 100 parts by weight of the rubber component, since the rolling characteristics are deteriorated and the effects to be produced by incorporation of silica may be offset if the amount of carbon black exceeds 30 parts by weight. It is preferable from the viewpoint of balance between the rolling characteristics and the abrasion resistance that the amount of carbon black is from 15 to 30 parts by weight per 100 parts by weight of the rubber component.

The rubber composition for tire treads of the present invention can contain usual other additives such as a curing agent, a curing accelerator, an activator such as zinc oxide or stearic acid, an antioxidant, a softener, a plasticizer and an inorganic filler such as calcium carbonate or clay, and may further contain, as occasion demands, a curing retarder and a tackifier.

The rubber composition of the present invention can be prepared and cured in a usual manner.

The present invention is more specifically described and explained by means of the following Examples in which all parts are by weight. It is to be understood that the present invention is not limited to the Examples.

#### Examples 1 to 5 and Comparative Examples 1 to 9

Rubber compositions containing varied amounts of a short fiber, carbon black, silica, a silane coupling agents and an oil as shown in Table 3 were prepared according to the recipe shown in Table 2 by mixing the ingredient in a Banbury mixer:

In these examples, a nylon 6 fiber having an average diameter D of 0.3  $\mu\text{m}$ , an average length L of 300  $\mu\text{m}$  and an L/D ratio of 1,000 was used in the form of a masterbatch wherein the nylon fiber was dispersed in and grafted to natural rubber through a coupling agent and the ratio of natural rubber to nylon 6 was 2:1 by weight (the masterbatch being available under the trade mark "UBEPOL HE-0100" made by Ube Industries, Ltd., Japan). Also, three kinds of carbon black shown in the following Table 1 were used as the carbon black.

Table 1

	Carbon black	
	Kind	Iodine adsorption number (mg/g)
(a)	N110	145
(b)	N220	121
(c)	N339	90

Table 2

Ingredients	Amount (part)
Natural rubber (RSS #3)	40
SBR	60
Short fiber	variable
Carbon black	variable
Silica	variable
Silane coupling agent	variable
Aromatic oil	variable
Wax	1
Antioxidant (6PPD)	1
Stearic acid	2
Zinc oxide	3
Sulfur	1.5
Curing accelerator	2.0

The amount of natural rubber shown in Table 2 includes the amount of natural rubber included in the short fiber masterbatch. Also, the SBR, silica and silane coupling agent shown in Table 2 are as follows:

SBR: styrene-butadiene rubber commercially available under the trade mark "SBR SL574" made by Japan Synthetic Rubber Co., Ltd.  
 Silica: commercially available under the trade mark "NIPSIL VN3" made by Nippon Silica Kogyo Kabushiki Kaisha  
 Silane coupling agent: bis(triethoxysilylpropyl)tetrasulfide commercially available under the trade mark "Si-69" made by Degussa Co.

The rubber compositions were extruded into a sheet in the form of a tread by a general extruder used in tire production, and the rubber sheets were cooled and cut into the predetermined size for tire production. Tires having a size of 185/65R14 were prepared in a usual manner by using the obtained rubber sheets in the tread portion.

The shrinkage of extruded tread, and the roundness, rolling resistance and abrasion resistance of tires were measured and estimated according to the following methods.

The results are shown in Table 3 wherein Comparative Example 9 shows a conventional rubber composition for a tire tread of low fuel cost type which contains only carbon black as the reinforcing material.

#### (1) Shrinkage of tread (mm)

The rubber sheet extruded in the form of tread from a rubber composition and cut to a length of 1790 mm was allowed to stand for 24 hours, and the length thereof was measured. The difference between the initial length and the length after 24 hours was represented as the amount of shrinkage.

#### (2) Roundness of tire

RFV (radial force variation) (load fluctuation force in the vertical direction appearing at the axis of rotation) was measured by a tire uniformity machine with respect to tires of 185/65R14. The larger the RFV value, the worse the roundness of tire.

The measurement was made under conditions of inner air pressure 2.0 kgf/cm<sup>2</sup>, load 396 kgf, rim 5.5JJx14 and number of revolutions 60 rpm with respect to 40 sample tire per each rubber composition. The average value of roundness and variation shown in Table 3 are those of 40 sample tires.

(3) Rolling resistance

The tire was attached to a rolling resistance measuring machine of drum type having a diameter of 1707.6 mm, and tested under conditions of inner air pressure 2.0 kgf/cm<sup>2</sup>, load 350 kgf, rim 5.5JJx14 and speed 80 km/hour.

The rolling resistance was represented as an index to the result of Comparative Example 9 regarded as 100. The smaller the index, the better the rolling characteristics.

(4) Abrasion resistance

The tires were attached to a 1600 cc car. Actual running test of the car was made and the amount of abrasion was measured.

The abrasion resistance was represented as an index to the result of Comparative Example 9. The larger the value, the better the abrasion resistance.

Table 3

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Com. Ex. 1	Com. Ex. 2	Com. Ex. 3	Com. Ex. 4	Com. Ex. 5	Com. Ex. 6	Com. Ex. 7	Com. Ex. 8	Com. Ex. 9
<b>Short fiber masterbatch (part)</b>														
Amount of masterbatch	9	9	9	9	9	-	-	45	9	9	9	9	9	-
Amount of short fiber	3	3	3	3	3	-	-	15	3	3	3	3	3	-
<b>Carbon black</b>														
Kind	a	b	a	a	-	a	-	a	c	a	a	-	a	c
Amount (part)	25	25	15	25	0	25	-	25	25	25	40	-	25	50
Silica (part)	30	30	40	50	50	30	50	30	30	15	30	70	30	-
Silane coupling agent (part)	3	3	4	5	5	3	3	3	3	3	3	7	-	-
Aromatic oil (part)	3	5	5	15	5	5	5	15	5	-	15	15	5	5
<b>Shrinkage (mm)</b>														
	8	8	10	7	12	35	42	5	8	11	7	9	8	12
<b>Roundness of tire</b>														
Average value	4.92	5.01	5.65	4.93	6.02	8.66	10.24	4.88	4.34	4.88	5.00	4.53	4.51	6.02
Variation	1.11	1.08	1.14	1.06	1.21	2.07	3.72	1.03	1.16	1.17	1.23	1.24	1.10	1.46
Rolling resistance	114	119	117	102	120	115	121	111	123	123	94	102	96	100
Abrasion resistance	107	102	101	117	105	110	103	91	84	87	115	110	79	100

As apparent from the results of Comparative Examples 1, 2 and 9 shown in Table 3, the rolling characteristics and abrasion resistance are improved by incorporating silica as a reinforcing material, but the shrinkage of tread rubber sheet increases and the roundness of tires is deteriorated.

It can be seen from the results shown in Table 3, for example, from comparison between the results of Com. Exs. 1, 2 and 9 and the results of Com. Exs. 3 to 8, that the shrinkage of tread and the roundness of tire are improved by incorporate a short fiber into silica-containing rubber compositions. However, even if such rubber compositions incorporated with a short fiber satisfy requirements of the tread shrinkage and the tire roundness, either the rolling characteristics or the abrasion resistance is not satisfied when the short fiber is used in an excessive amount (Com. Ex. 3), when carbon black poor in reinforcing ability is used (Com. Ex. 4), when the amount of silica is too small (Com. Ex. 5) or when the amount of carbon black is too large (Com. Ex. 6).

In contrast, as apparent from the results shown in Table 3, the rubber composition of the present invention can provide tires having excellent in rolling characteristics, abrasion resistance and dimensional stability. Also, it can be seen from comparison between the results of Examples 1 to 3 and the results of Example 5 that the tread shrinkage and the tire roundness are further improved by replacing a part of silica with carbon black as a reinforcing material, although the rolling characteristics are somewhat deteriorated.

Comparative Example 7 is an example according to the present invention wherein silica is used in an amount exceeding 60 parts, namely in an amount of 70 parts. The rubber composition of Com. Ex. 7 has satisfactory rolling characteristics, abrasion resistance and dimensional stability, but further improvement thereof conforming to the use of an increased amount of silica is not obtained as compared with the use of a less amount of silica and, therefore, the use of such a large amount of silica is not economical.

In addition to the ingredients used in Examples, other ingredients can be used in the Examples as set forth in the specification to obtain substantially the same results.

#### Claims

1. A rubber composition suitable for tire treads comprising a rubber component, 20 to 60 parts of silica, 3 to 12 parts of a silane coupling agent, and 2 to 10 parts of a short fiber, said parts all being parts by weight per 100 parts by weight of said rubber component.
2. The composition of Claim 1, wherein said short fiber has an average diameter of 0.1 to 0.5  $\mu\text{m}$ , an average length of 50 to 500  $\mu\text{m}$  and a length/diameter ratio of 100 to 5,000.
3. The composition of Claim 1, which contains 0 to 30 parts by weight of carbon black having an iodine adsorption number of 100 to 190 mg/g per 100 parts by weight of said rubber component.
4. The composition of Claim 1, which contains 15 to 30 parts by weight of carbon black having an iodine adsorption number of 100 to 190 mg/g per 100 parts by weight of said rubber component.
5. The composition of Claim 1, wherein said rubber component is at least one member selected from the group consisting of natural rubber, isoprene rubber, butadiene rubber and styrene-butadiene rubber.
6. The composition of Claim 1, which contains 30 to 50 parts by weight of silica and 15 to 30 parts by weight of carbon black having an iodine adsorption number of 100 to 190 mg/g.
7. The composition of Claim 1, wherein the amount of said short fiber is from 3 to 5 parts by weight.
8. The composition of Claim 1, wherein said short fiber is at least one member selected from the group consisting of synthetic fibers, semisynthetic fibers and natural fibers.



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## EUROPEAN SEARCH REPORT

Application Number  
EP 95 30 9482

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 265 070 (UBE INDUSTRIES) 27 April 1988 * page 11, line 33 - line 34; claims 1,10 *	1-8	C08J5/04 B60C1/00 C08L21/00
A	--- DATABASE WPI Section Ch, Week 8929 Derwent Publications Ltd., London, GB; Class A95, AN 89-209364 XP002000887 & JP-A-01 145 205 (SUMITOMO RUBBER IND KK) , 7 June 1989 * abstract *	1-8	
A	--- EP-A-0 329 589 (GOODYEAR TIRE & RUBBER) 23 August 1989 * claims 1,8,9 *	1-8	
A	--- EP-A-0 620 250 (GOODYEAR TIRE & RUBBER) 19 October 1994 * page 2, line 14 - line 45; claim 1 *	1,3-6	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			C08J B60C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 18 April 1996	Examiner Van Humbeeck, F
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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